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ABSTRACT

In order to investigate the text structure/reading comprehension relationship, this paper reviews recent research on text representation theories. Text structure investigation--research on semantic memory as it is concerned with meaning from the word level through the inference level--follows the premise that sentences are understood in the context of their use if the comprehender has the ability to project meaning to the concept. Five models of text structure, intended to explicate the comprehension of reading, are examined in the paper: (1) Crother's logical relations model; (2) Meyer's hierarchical organization model; (3) Frederiksen's constructive model of discourse proceeding; (4) Kintsch's model of semantic memory; and (5) the Anderson and Reder encoding elaboration model. The paper explains the analytic system of each model, in which text comprehension is assessed by comparing author intent with reader recall. The theoretical base and distinctive features of each model are detailed, and the methodology and findings of supporting research are reviewed. Other issues addressed in the paper include how text structure influences the structure created by the reader, how it reflects what is learned and retained, and how it affects information retrieval from the semantic knowledge structure of human memory. (Seven pages of references are appended.) (MM)

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Text Structure and Reading Comprehension:
The Development of Five Structure Models
and Issues in Comprehension of Expository Prose

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TEXT STRUCTURE AND COMPREHENSION

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Abstract

This article reviews five models of text structure intended to explicate the comprehension of expository prose. The theoretical base and the distinctive features of each model are detailed. The paper explains how each model analyzes text structure and assesses reader comprehension. It reviews the methodology and findings of supporting research. The concluding section discusses the models in relation to critical issues in reading comprehension: reader structure, learning and retention, and information retrieval from semantic memory.

Text Structure and Reading Comprehension: The Development of Five Structure Models and Issues in Comprehension of Expository Prose

Introduction

This review was conducted to establish the rationale for a study of the effect of text structure on the comprehension of new information in passages of connected discourse by sixth graders. It examines five models of text structure that are used to assess reading comprehension, the theory from which each evolved, the supporting research, and how each model addresses the critical issues in reading comprehension. Development of each model over a span of years reveals a shift in emphasis from the structure of language to the processing of language. Systems of text analysis developed from advances in linguistic analysis of language and in information processing models intended to describe cognition. In the analytic system of each model, text comprehension is assessed by comparing author intent with reader recall. The issues addressed in this paper include how text structure: (a) influences the structure created by the reader, (b) reflects what is learned and retained, and (c) effects information retrieval from the semantic knowledge structure of human memory.

Text structure investigation is research on semantic memory (Kintsch, 1980) as it is concerned with meaning from the word level

through the inference level. It follows the premise that sentences are understood in the context of their use if the comprehender has the ability to project meaning to the concept. Evidence for this position was provided by Bartlett's (1932) constructive theory of remembering as he explained the transformations seen in the successive recall protocols gathered in his investigations of remembering. He attributed the choice of detail around which an individual constructed selected features to individual salience. He described the characteristics of the recall pattern from the method of repeated reproduction that followed the reading of the passage. These characteristics included consistency of form, stereotyping of salient items, omission, simplification, transformation toward the familiar, and elaboration, which Bartlett called importation or invention. Over long periods of time, the subject's attitude toward the material remained constant, supporting the premise that it is the comprehender's ability to project meaning to a concept that allows learning and retention. The details that are meaningful to the subject may be transformed, but they take a progressively earlier place in successive reproductions. Bartlett's name for this constructive process of transformation is rationalization.

In his memory experiments using picture writing, Bartlett's findings foreshadow van Dijk's (1977) and Frederiksen's (1972, 1975c) processes of deletion in the absence of a referent for a concept. Bartlett found that in any presented material, signs unrelated to other signs to which subjects had previously reacted

were omitted. Signs with no representational significance, and those that were imprecise or ambiguous were also omitted.

Evidence from Bartlett's work that long term memory is primarily inferential includes his findings that: (a) The most unstable elements are headings, titles, and proper names; (b) there is a bias toward the concrete, indicated by omission of argument, reasoning and deduction, and personalization, that is, providing a moral when the story had none; (c) the more familiar the passage content the greater the reductions; the less familiar the content the more connections the reader must infer. Bartlett found that position as a factor in recall had no relevance for familiar material. The material of superior interest displaced material early and/or late in the passage.

Dawes's (1964) work was the first investigation into semantic representation of prose since Bartlett (Reder, 1980), and a precursor to the theories of Crothers (1972a, 1972b) and Frederiksen (1972, 1975a, 1975b, 1975c). Dawes presented a system for the structural analysis of the cognitive distortions that occur when a belief is maintained in the face of contradictory information. He investigated the set relations in a passage of informational narrative discourse, hypothesizing that simplification of the relations would occur over time. In his conception, all declarative statements assert relations between sets that represent common beliefs. If these set relations are directly contradicted, cognitive distortions occur.

Dawes (1964, 1966) defined his relations in terms of syllogistic logic: (a) exclusion—no x are y, (b) identity--all x are y, (c) inclusion--some x are y, (d) disjunction--some x are not y. The first three categories are nested relations; disjunction is an overlapping relation. Dawes hypothesized that overgeneralization, remembering a disjunctive relation as nested, is a measure of simplification, information reduction, that reduces the number of categories of response. For example, in his Circle Island story (Dawes, 1964) the statement some senators belong to the pro-canal association would become all senators belong to the pro-canal association or no senators belong to the pro-canal association. His second distortion, that a nested relation is disjunctive, increases complexity and changes no senators are farmers to some senators are farmers or all senators are ranchers to some senators are ranchers. Dawes called this change pseudo-discrimination. Changes in logical relations are inferences.

Dawes exposed his subjects to two passages that concern political and/or economic groups. He scored recall protocols in his investigation according to the set relations specified in the passages. He measured both distortions and memory selection. His expectation that overgeneralization would exceed pseudo-discrimination in the immediate condition was supported. Confidence ratings for the correctness of selected responses indicate that overgeneralizations are selected as correct responses more than pseudo-discriminations.

Dawes contrasted the empirical investigation of his premises to the work of Bartlett (1932). The differences include: (a) a recognition task--choosing the correct alternative statement, one nested and one disjunctive--rather than free recall as the dependent measure; (b) test immediately after exposure, not at delay, and (c) interest in distortion as a function of structure, not content.

Dawes extended his premise to include the idea that further simplification would occur with delay. Using alternative statements and recalls as dependent measures, he found poor recall accuracy, and simplification, but no increased simplification after a three day delay. Noting increased accuracy in the recognition task at delay, and the lack of clear cut evidence in the recalls, Dawes contrasts his findings to those of Bartlett. He attributes Bartlett's findings to the confounding of simplification and forgetting. However, he fails to account for differences between a three day delay in his study and Bartlett's intervals of weeks, and months, and in a few cases years, no less the differences in the nature of the material. Reder (1980) interprets Dawes's results as evidence that inference occurs at input or output rather than relating to forgetting.

The present paper reviews recent research that deals with expository text. This is in contrast to the North American Indian folk tale used by Bartlett which required a greater <u>effort after meaning</u> because of the gaps in its logical structure (Spiro, 1977), resulting in distortions and importations neither anticipated nor

found with expository text. Since the majority of studies involving expository material have used university students as subjects, the results reported in this review are for this group, unless otherwise specified.

Components of Text Structure Models

The following five models will be discussed. Each represents underlying structure in a different way, while comparing the semantic structure of the prose passage with the semantic memory representation constructed by the reader.

1. Crothers's (1972a, 1972b) logical relations model identifies concepts on two levels, arranges the levels hierarchically, and constructs a superordinate, referential graph structure capped by text based inferences. In its extension, the inferable text cohesion model (1978, 1979a, 1979b), inferences are classified into three types based on the principle of text coherence. The model is based on a descriptive theory at the text level of analysis.

2. Meyer's (1975a, 1975b) hierarchical organization model identifies the function of the information or content structure in the text, classifies relations at the idea level for the overall passage and at the word level, and constructs a single hierarchy that incorporates both levels using rules that generate subordinates. The extended theory (1977b, 1979) investigates the memory facilitation of rhetorical predicates.

3. Frederiksen's (1972, 1975a, 1975b, 1975c) constructive model of discourse processing incorporates two stages. The first level of semantic structure is similar to Meyer's structure without the level of relations. To relate the concepts in the structure, a logical relations graph, similar to Anderson's (1976) network representation of semantic memory, is added to the hierarchical proposition structure. Later work (1977a, 1977b, 1979) emphasizes the dual nature of text comprehension--the recovery of propositional structures and the derivation of inference.

4. Kintsch's (1974) model of semantic memory is based on propositions that describe or generate text. Van Dijk's (1977) process theory explains the transformation from surface structure to macrostructure. Kintsch and van Dijk's (1978) combined process model constructs a hierarchical representation of prose from the propositional representation of concepts in the passage, according to schema-based, but rule-governed, operations.

5. The Anderson and Reder (1979) encoding elaboration model is an explanation of learning and memory functioning during language-learning tasks, and a component of the ACT model (Anderson, 1976). Elaboration of text content takes place at all three stages of cognitive processing: during the reading or encoding stage, while the information is stored in long term memory, and when the information is retrieved from long term

memory. The theory is applied to memory for prose passages, learning new information from text, and the relation of elaboration to depth of processing.

Inferable Text Cohesion—Crothers

Early Model

Crothers's (1972a, 1972b) early model attempts to represent the organization of human memory by emphasizing logical relations in a passage, not surface structure, and the integration of new information in semantic memory. In response to empirical findings, he changed the model when graph structures based on semantic hierarchies and logical relations could not be constructed from readers' recall protocols.

Crothers's (1972b) aim was to formulate an explicit psycholinguistic theory of comprehension and memory for prose that would address the learning of new information and its storage in long-term memory. He criticized theories that attend only to the retrieval of well known information from long-term memory, or that deal with abstractions from passage content. His data indicate that these theories are inadequate to explain the cognitive processing of text. The model proposed by Crothers was intended to account for paragraph organization or theme, and the implied propositions that change semantic salience. This concept necessitates: (a) accounting for both underlying and surface structure of a descriptive prose paragraph, (b) experiments to discover the structural correlates

which permit inferencing, and (c) a process model which specifies operations complementing the structure model.

Crothers (1972a, 1972b) states that the proper unit of analysis in memory and discourse is an overall knowledge structure, not a set of independent sentences. To determine the relation between prose structures and memory structures he used data from prose recall tasks. Crothers described the linguistic structure of short descriptive passages and compared recall protocols representing memory structure. This between-sentence semantic analysis characterized stimuli and described response scoring within the framework of his theory.

Crothers's analysis system produces a separate outline for each semantic hierarchy or proposition. The meaning-bearing words are ordered from subordinate to superordinate, from left to right, with the words indicating set relations in the superordinate position to the right in successive cycles of a tree structure. Each graph is meant to be an abstract summary of a passage which contains characteristics of the object described and logical relation words.

Crothers lists the factors of linguistic analysis that must be included in a graphic representation of a paragraph. Underlying linguistic structure is not sufficient for his superficial structure; sentence order and frequency of concept occurrence must also be available. The number of explicit and implicit occurrences of each set relation must be clearly noted in the structural representation. Crothers finds that neither his proposed structure

nor the linear propositional notation can include all necessary elements.

To test his system, Crothers (1972a) presented four paragraphs on different topics in random order. Before reading, the subjects wrote a prior knowledge summary on each topic. Then, each subject read the passages printed sentence by sentence on a deck of cards. The first passage was tested for recall immediately; all four passages were tested for recall one week later.

In the passage of primary interest for the study, sentence order was varied to produce alternative versions. Each version was presented to a randomly selected half of the subject population. The passage was linguistically analyzed as a hierarchy of concepts for comparison to the recall protocols. Each tree graph structure showed the logical connectives or set relations within the passage for each hierarchy of concepts.

The data were scored for underlying structure. Both stated and implied propositions were included; ambiguities were assigned compatible reference points within the passage. Data scores were calculated for nodes or concepts, and for relations or correspondences. Correspondence errors reduced or to and, and why to and. Logical relation errors and omissions were scored according to Dawes (1964, 1966). The recalls contained few intrusion errors or spontaneous comments that did not fit the taxonomy of anticipated responses.

A problem resulted from using the tree graph structure to score

the protocols. Subtopic dependencies could not be attributed to superordinates. Crothers concluded that the recall of each major subtopic is independent of other major subtopics. He then defined three major subtopics, assigned each concept in the recall to a subtopic, and performed an analysis. He found no significant differences between the independent subtopics. However, within categories, if one idea was recalled, related ideas were also recalled.

This study found no difference that could be attributed to the varied sentence order of the two versions of the primary passage. There was no difference between subjects tested in the immediate condition and at one week, and those tested at one week only. Superordinates were not recalled more often than subordinates. Secondary subtrees, those not dominated in the graph structure by the main WHY node, were not recalled less frequently than the subtrees higher in the graph structure. Despite the lack of significance in the empirical data, Crothers's pursued the explicit outline form of hierarchic structure, the notion that the outline of a reader's protocol should be in accord with an outline of the passage. He concludes that theme must be redefined to include frequency of occurrence, and that the final step in building the paragraph structure is to derive the foregrounded structure, or the selective emphasis influential for comprehension and memory.

Crothers conceptualized foregrounding as a graph structure that falls between the paragraph and the underlying structure, a form of

macrostructure. He explains foregrounding as analogous to syntactic transformation; the semantic content is not changed, but a focus is established. He views the development of a formal theory of foregrounding as essential to the psychological application of the model.

Reder (1980) criticized the limitations of Crothers's conception. She states that: (a) Set relations are only appropriate for richly descriptive passages similar to those he used, not for prose in general; and (b) his view of the reader's memory structure is limited to set inclusion inferences; it is not broad enough. Spiro (1975) places Crothers's work in the abstractive-trace retrieval category in which accurate recall is anticipated and importations and distortions are the exception.

Crothers's (1972b) next major experiment was to determine if passage theme or gist is remembered best when explicitly stated or implied. Passage content was graphed according to the foregrounding structure model with one of four passages foregrounded in two ways. Subjects recalled the first paragraph immediately and all four after a week's delay. Results of the study were inconclusive; this was attributed to scoring problems.

In other studies (Crothers, 1972b), subjects generated recall outlines compared to the foregrounded graph, and randomly arranged graphs were used to see how locations affect memory. Few results are available, but Crothers concludes that the structure model provides a relatively objective and complete method for scoring

recall protocols. The data do not support his hypotheses that the theme is recalled better than nonthematic content or that higher-level nodes are recalled better than lower-level ones and principal subtrees are better than parenthetic ones. However, the data reveal that the correlation of structural factors with recall was based solely on a node's frequency of occurrence within the passage. Crothers interprets this finding as support for predicting recall from the foregrounded graph, not the underlying one.

Descriptive Model

Crothers (1978, 1979a) developed a psycholinguistic theory of text structure by applying his model to the role of inference in passage comprehension. In this descriptive text level analysis, syntax and semantics are subsumed by the proposition structure. Inferences are classified as: (a) propositions--presupposition, premise, and consequence; (b) proposition elements--insertions, substitutions, and additions; and (c) proposition connectives--logical or semantic relations. This taxonomy guides inference classification. The analysis of the explicit text is based on three classes of text properties: (a) regularizations--parallel propositions, proposition elements, proposition order; (b) categorizations--spatial, temporal, animate, action/being, manner, inanimate/concrete, inanimate/abstract; and (c) figurative interpretations--metaphor, simile.

Five simple passages, argumentative and narrative in rhetorical mode and diverse in style with respect to explicitness and focus,

were described in tree graph form at the text level (Crothers, 1979a). Text cohesion, that is, connectivity, coreferentiality, and lexical comparison and contrast, is the criterion for text level representation of inference. The complete description of the explicit text is extended to include the generation of plausible inferences. The taxonomy for each class of propositions serves as the rules for the analysis. Crothers's purpose is to establish rule-based specificity with the goal of applying the system to research on reading comprehension and memory. The statistical summary of the four passage descriptions is included as a measure of the utility of the principles--average frequency of application across passages and frequency variation between passages.

Crothers (1978, 1979a) recognizes the impossibility of representing all knowledge necessary for inference in a long, complex text. Future application of the system to both greater numbers of texts and longer texts depends on simplification. Possible analytic limitations include inferences having multiple antecedent/consequent connections to other propositions, using larger units of analysis, using a within-paragraph theme, and selective rule selection. Crothers states that the present analytic theory does not provide for the generation of texts, but can be used to edit text in respect to the revealed structure.

Three Systems of Text Structure

As Crothers's theory develops, inference and interconnectedness are incorporated into more complex and more complete text

representations against which recall protocols can be matched. Three systems are being developed (Crothers, 1979b) to explain text structure: the logical proof method, the system of parallelism, and the list graph. The latter, based on textual cohesion derived from parallelism and sensitive to structural ambiguities and reader interpretation, is a reflection of Crothers's earlier (1972a, 1972b) model.

Crothers (1979b) developed the theory of inferable text cohesion from work in text structure revision that yielded limited empirical results. He explains the system as follows: A text is viewed as a proof in the sense that its topic sentence can be considered a theorem derived from the sentences that develop it. The proof terminates when all the explicit sentences in the text are included. The proof can be expanded by the principles of inferential text coherence, an element that appears in several of the proposed representations of text. On a pragmatic level the proof can terminate earlier leaving the explication of the details to the reader.

The theory defines the proof as derived from a logical calculus. The axioms are the propositions in the text that are not consequents of other text propositions, that is, they are text specific. The derivation of one proposition from another must be looser than in a true deductive system. To formalize the proof of explicit text sentences a great number of inferences must be included. The system works from the consequent to the antecedent

that provides the proof. Sentences or parts of sentences are the units of the proof. The surface form is frequently in a sequence that states a thematic conclusion first, follows with subthematic antecedents, then includes causal, chronological, or logical beginnings that refer to the stated theme. Therefore, the method for text proof proceeds backwards from consequences to antecedents recursively. Surface form determines whether sentences are joined to form larger units, broken down into smaller units, or sentence order is transformed. For example, if a cause is made into a topic followed by its effects, the proof is said to be antecedent-raising. Conclusions may precede or follow their arguments.

Crothers favors the proof form over a graphed text form because each proof line can be annotated. If a text passage contains propositions that have several consequents, Crothers believes the structure is analogous to a true proof. Because of its tediousness, the proof method can be restricted to the interconnected segments in a passage. Crothers finds graph representation less abstract than proofs which separate antecedent/consequent relations from connectives. A text can be represented as a standard form and a variation on a standard form, and multiple texts can be compared, that is, different sequences and parsings can be diagrammed for the same content.

Crothers (1979b) conducted a series of experiments to provide support for his three developing methods of analyzing text

comprehension and memory. He found that text revisions based on attempts to reflect text cohesion were not successful, so he based them on the proof method. The restructured passage consistently presents the main conclusions before the proofs. In a comparison between the original version and the revised version, using the results of fill-in and multiple choice tests, the revised version led to significantly better results only on the fill-in or more content explicit test form. When a second text was rewritten according to the proof method, the results showed a significant advantage for the multiple choice test for both revisions, and an advantage on the fill-in test for one of the revised passages.

Crothers also tested various adjunct aides to comprehension. For example, he investigated direct cohesion among explicit text sentences by inserting inferential connectives. Test questions were directed to these inferences and their connections to the explicit text sentences. The subjects were given one text proposition, the consequent, and the backward connective. They were asked to recall the antecedent proposition. A control group read the three passages in an ordinary format and answered the questions, while the experimental group read revised versions and answered the questions. The subjects read each passage twice before answering the questions. All results, text, group, and the group by text interaction, were significant. Adjunct connective insertions led to increased accuracy at post-test, and did not increase total reading test time. The experimental group took a longer time to read the

passages and a shorter time to answer the questions.

This experiment is of interest because the experimental condition inserted unusual redundancies that interrupted the flow of the connected discourse passages. The responses to highly cued questions were scored. A free recall after delay might have been a truer measure of text comprehension and memory.

Crothers's (1979b) second developing method of analyzing text structure is parallelism. Applying the system of parallelism to the Circle Island passage (Dawes, 1964) explicates the microstructure which indicates the overall organization or major constituents of the passage, the macrostructure. Crothers sets up propositional chains across the page that parallel each other in a graphic representation as they are thought to do in the text. Chains 1-4 explain the actual situation, chain 5 explains the conditional situation, and chain 6 explains the desired or not desired situation. In this system, implication must parallel explicit chains, and may be forward or backward, proceeding from past information or referring backward from following information.

Each parallel subgraph in the structure deals with one aspect of the text. For Circle Island the first subgraph is principles versus practices of conflict resolution; the second is geographic-economic conditions; the third is implementation of the government's principles; the fourth is resolution and potential conflict. A global structure can be inferred from the subgraphs. This structural representation of text content is interconnected from

left to right as were Crothers's (1972a, 1972b) earlier tree structures. It represents an antecedent/consequent ordering rather than a hierarchy.

The list graph system resulted from parallelism. It uses proposition lists as nodes that can be expanded by abstraction. The system handles subordination as well as parallel cohesion and has implications for hierarchicality and macrostructure.

Crothers (1979b) designed a series of experiments to provide data to support the theory of parallelism. In these, the emphasis shifts from his preceding work on connectives intended to facilitate comprehension to a process approach to inferences made during reading. Crothers inserted comprehension tasks into the reading, and compared performance against memory data on a post-test for inferencing of antecedents and consequents. He assessed text connections, the associations within the paragraph identified by the theory. The studies used the Circle Island (Dawes, 1964) passage.

In one study the experimental task was to arrange the text sentences into a coherent paragraph. Inferences were tested by choosing antecedents for stated consequents. One dependent measure was the distance between the subjects' paragraph protocol and the ideal arrangements when compared sentence by sentence. The two ideal arrangements were presupposition or topic ordering, and premise ordering, both of which minimize the distance between an antecedent and its consequent.

The results of this study were inconclusive. There was an

expected negative correlation of the sentence distance with the scores on the 12-item performance post-test which was significant for premise ordering. Crothers would like to have attributed the post-test performance to the inferencing done during sentence arrangement, but there was no way to measure when the inferences were made. Therefore, he designed investigations to assess inferencing during reading.

The next group of studies used the sentence ordering task to examine comprehension of text coherence relations. They were operationalized on a computer. Since previous studies showed a greater correlation between premise ordering and the post-test performance than between presupposition ordering and post-test performance, the task was performed on a computer terminal. It was expected that the steps taken to obtain the final arrangement and the time interval between steps could be recorded as an index of inter-sentence cohesion. In addition, another study investigating individual differences in text cohesion was designed to assess whether a subject prefers premise or presupposition order. It was anticipated that performance on the post-test would correlate with organizational choice. Individuals preferring the premise organization should do well on fill-in and multiple choice tests; individuals preferring the presupposition organization should do well on writing an outline of the passage. The data for these studies have not been analyzed.

In two other studies (Crothers, 1979b), five sentences in the

passage were transformed so that they were implausible consequents. As each sentence was displayed, the subjects made a plausible/implausible judgment. Immediate feedback that was meant to minimize comprehension errors failed to reduce confusion. Modification required a forced-choice judgment only between the five transformed sentences and their corresponding originals. No feedback was given. An inference post-test based on the antecedent/consequent relation followed. All five text inferences were included in the post-test.

Results indicate that consequents are recognized as not being antecedents more than antecedents are correctly identified. Latency results for the directness of the antecedent relationship approached significance in the expected direction. A direct antecedent was more quickly identified than was a remote antecedent. A remote consequent was more quickly identified as not being an antecedent than a direct consequent. There was an interaction of directness with response.

The same results were obtained in a replication study that added control groups, enlarged the sample, and reduced the post-test to six items that tested the direct-remote/antecedent-consequent inferential relation. One group of subjects was probed for antecedents, one group for consequents, and a third for antecedents and consequents. Results show the antecedent group did best on the forced choice during reading. The antecedent group did significantly better on the post-test.

These results suggest that readers are better able to decide whether a test sentence in the text is an antecedent of a key sentence rather than whether or not it is a consequent. This finding was in opposition to the hypothesis that a sentence is associated with its consequents more than its antecedents. No significant effects of directness versus remoteness were found, but direct sentences are more often responded to correctly when they exhibit the relation questioned than when they do not, 72% to 54%. Remote test sentences are identified more easily when the related question is not the correct one, 68.2% to 56.8%. Crothers concludes that subjects associated direct relations with correctness and remote relations with incorrectness.

Crothers tends to analyze empirical data to the extent that they indicate a direction for further experiments. He is looking at passage coherence through reader inference and through text structure. The nature of his approach is indicated by his continuous development of theory to justify data and his generation of new data to provide support for theory. Crothers's work is creative, holistic, and of theoretical interest. Although several of the empirical studies were based on one passage, Circle Island (Dawes, 1964), written to express specific relations, he derives support for his descriptive model from studies using different passages. This model includes provision for text structure ambiguities and differences in interpretation by incorporating the list graph--proposition lists--as nodes, and superordinate/

subordinate recurrences of the same proposition as cohesive relations in text. It has implications for issues of hierarchicality and macrostructure of text.

Case Relations and Network Structure--Frederiksen

Constructive Model

Frederiksen's constructive model of discourse processing (1972, 1975a, 1975b) is similar to Crothers's (1972a, 1972b) in its emphasis on defined and inferred relations within the passage. Frederiksen represents knowledge as highly structured propositions. He diagrams interpropositional structure of the passage as a complex network of concepts. Semantic relations connect the concepts in the networks. The concepts and relations are graphically represented as multi-level tree diagrams. The referential coherence of the superordinate concepts makes up the logical structure graph; semantic primitives and case designations make up the semantic network. Passage representation includes the concept labels and the interpropositional relations necessary to indicate reference and inference. The model is intended to represent the structure of semantic memory as abstract data structures. It is general enough to represent texts of many kinds.

In Frederiksen's (1975c) system, a text can be analyzed into a set of logical structures with the concept relations specified in the network structure. Alternatively, a series of propositions arranged in a network structure can be used to generate a short

narrative. Concepts generate lexical items, and relations are structurally related by grammatical rules. The system includes detailed procedures for deriving representations of text for comparison to reader recalls.

In Frederiksen's theory, the central issue is the identification of processing units in text comprehension, production, and representation of semantic memory: (a) The structure of any text is a reflection of the knowledge structure of the author; (b) language is a representation of human memory structure; (c) recall occurs in clusters of mutually dependent items of higher order units; (d) partial recall is not random, but a highly structured subset of items of information from the text; and (e) understanding results from analysis of the text into highly structured semantic units. Empirical data support discourse processing as a multilevel ranked structure with processing units varying from single concepts to networks of connected propositions or macrostructures.

Major components of the model include: (a) explicit definitions of all underlying semantic relations that serve as restrictions on the two concepts in the binary propositional relation and the connecting relation; (b) a semantic network that consists of labeled binary relations that connect concepts; (c) a logical network that serves as a substructure of the semantic network consisting of labeled binary logical, causal, or algebraic relations to account for relative and negative information that cannot be accounted for in the semantic network; and (d) propositions containing additional

examples of case-type relations.

Within the networks of the semantic structure, the semantic network relates concepts like events or states; the logical network relates propositions building superordinates or chunks of meaning. For example, the logical subsystem relates propositions by probability, the if-then clausal connection; the causal subsystem connects propositions by causality, because; the relative system measures propositions against each other quantitatively, greater than and other comparatives and superlatives.

Frederiksen used the same materials and methods to investigate variants of the problem. He studied the acquisition of information under different task conditions in order to contrast superordinate processing modes employed by subjects (1972). He represented the text in graph form expressing set relations among concepts and implications among propositions since the process model operates differently depending on the text content.

Frederiksen provided evidence for his model by assessing the semantic knowledge contained in a discourse recall, and comparing the recall with the set relations, identity relations, and conditional relations identified in the text structure. Frederiksen (1975a) collected data to support the process interpretation that adjustment to information overload occurs at acquisition through selective processing, not at recall. His method of repeated exposure--listening--to a text was expected to influence the frequency of conceptual and relational information in the subjects'

written recalls. These, in turn, were expected to include the reproduction of a text as paraphrase, plus the conceptual and relational information derived from the text in overgeneralized--reduced or simplified--and inferred form. Frederiksen's assumption was that information acquired inferentially or through overgeneralization becomes an integral part of the subject's memory for the text and is not altered with repeated readings. He cites the presence of derived information in the recalls as evidence for a constructivist position. In addition, he finds that the processing load decreases with repeated exposure, and reduces the need to process the remaining information selectively.

The next study (1975b) focused on the invariance of processes. If a text is understood differently in different contexts, then the context should produce differences in how the text is processed. Therefore, Frederiksen structured the context to induce the generation of inferences by establishing a problem solving purpose for reading. He expected that subjects would process the text selectively, omitting information not necessary for the solution of the problem as a response to the increased process demand.

Repeated exposure--listening--was the method, and written recall after each exposure was the dependent measure. The material was adapted from Dawes's (1964) Circle Island story. Dawes's objective test and his categories of simplification based on nested and disjunctive set relations were part of the procedures. Three context conditions were established. Each group listened to the

text four times, and recalled after each exposure, comparing the recall to the text base. The first group was instructed to read and recall, the second was told to recall and problem solve, the third was told to problem solve only. Only after the fourth reading was the third group expected to recall. These conditions established incidental problem solving for the first group, and incidental memory conditions for the third group. All readers were presented with the problem for solution after the fourth recall. At a one week delay, recall reflected the memory structure of the acquisition conditions. Greater numbers of inferences were expected from group one at delay since the problem solving instruction should generate more inferred semantic information.

The recall responses were placed in six categories: (a) equivalent or veridical, (b) overgeneralized or simplified, (c) pseudo-discriminated--overspecified or innacurate, (d) transformed, (e) inferred, and (f) elaborated. The results indicate that the same amount of reproduced information was generated by groups one and two. The conditions for these groups had a significant effect on the frequency of overgeneralized concepts. Problem solving produced a greater number of overgeneralized concepts. There is a significant effect of trial, with an increase from trial one to trial two, and a slowing of amount generated for trials three and four. Evidence is clear that the overgeneralizations found in the recall of trial one become part of the memory for the passage.

Results indicate that problem solving context produced greater

numbers of overgeneralized responses than the recall only group, and support the hypothesis that frequencies of overgeneralized and inferred concepts and relations will show negatively accelerated increases over trials. Frederiksen's interpretation was that overgeneralization reflects reduction of non-essential information and inferred concepts, and relations reflect procedures for inferring text content without completely analyzing each input sentence. He also states that these studies indicate the validity of comparing subject recall with text structure as a method of inferring the processing operations.

According to these findings, problem solving affects the contextual effects of derived information and leads to greater amounts of inferred concepts and relations in recall protocols. The condition requiring solution only, not memory, leads to more elaboration and more memory errors. The differences found between groups one and two in the immediate condition continued to be evident after a one week delay. Therefore, Frederiksen states that the acquisition conditions have lasting effects on memory structure. In all three conditions, the findings of increased simplification are analogous to Bartlett's findings of greater loss of reproduced information than of derived information.

Reder (1980) disagrees with Frederiksen's explanation that problem solving leads to more inferences at recall because an increased processing load leads to simpler encoding. Reder interprets the greater number of inferences drawn at input as

evidence of more processing, not less. Since both the memory group--read and recall--and the problem solvers--recall and problem solve--produced greater amounts of recall than the problem solve only group, Reder explains semantically relevant memory errors as the outcome of a meaningful orienting task. According to the theory, a greater processing load should lead to greater information loss, which did not happen.

Two Level Model

After the development of the two level model of text processing, Frederiksen, (1975c) collected additional data to support the extended explanation. As before, he compared recall protocols to the text template. However, the template now has a network representation of conceptual relations superimposed on the hierarchical propositional representation of the text base. The text information is still coded as logical and semantic information. A set of logical structures is laid out with the concept relations specified. In the advanced system, a series of propositions arranged in a network structure can be used to generate a short narrative. Concepts generate lexical items; relations are structurally related by grammatical rules.

In the experiment, kindergarten children listened to a narrative generated from a propositional structure. Their retellings were scored item by item against the network. The analysis compared the proportion of items in each category against the text template. The findings indicate that sets of items are recalled as chunks; the

chunk structure corresponds to the embedding structure in the network. The retellings indicate that embedded propositions can be processed as independent units and individual operations can be deleted, that case systems are processed as structured units, and that goal information is processed independently of its case system.

Deletions and replacements of individual items indicate that the details of the network are valid representations of units of information. Information was generated or inferred from implied items in the representation. Generation of information not represented in the network is representative of fundamental comprehension processes. The network acts as a structural whole affecting the acquisition of its parts.

A theoretical difference exists between Reder and Frederiksen as a result of Frederiksen's (1975a, 1975b,) assumption that inference represents attempts to generate missing or nonretrievable material; it is either gap-filling or distorting. Reder (1980) notes that Frederiksen's model includes inferences, which should make it a more realistic representation of what long term memory structure may be after comprehension of a prose passage. However, Reder views inference as integral to comprehension at all levels and states that representation of an entire text should focus on higher order complexities. Frederiksen's system appears to Reder (1980) to emphasize relations within a sentence, rather than relations between sentences, as exemplified by the decomposition of concepts and relations into semantic primitives. Complexity in this model is at

the wrong level, and does not represent passage comprehension. The connection of propositions temporally and referentially at the network level is insufficient. No provision is made for overall organization and inferences that connect the text elements. Crothers (1979a) comments that the theory is formulated at the semantic level and ignores text inference and coherence.

Levels of Discourse Comprehension

Later versions of Frederiksen's model (1977a, 1979) specify two levels of discourse comprehension that involve propositional data structures. At the interpretive level, propositional knowledge is recovered from text; at the inferential level, new propositional knowledge is derived from a network that may be made up of prior discourse, context, or stored knowledge of the world. Inferences can function at any level in this system and may define higher-order semantic units, that is, referentially related propositions may form the basis for inferring from one proposition to the other as an aspect of understanding a text. Further, if referential propositions are implied rather than explicit, the inference represents discourse processing not discourse structure.

Frederiksen's concept of multi-level propositional networks specifies the propositional content that is explicit in a discourse. There are six ranks or levels in the system. The concept is the simplest level. At the second level, two concept slots are connected by a relation so that the category to the left is a superordinate and the category on the right is a subordinate.

These relational triples are further connected to build several levels of complexity. The third level is an event frame, a system of relational triples connected to an action. At the fourth level, the proposition represents an event or a state, that is, the time, location, the nature of the event, or the attributes are specified. The fifth level specifies relative systems, comparisons involving time, location, attributes or actions. The sixth rank and most complex level is the dependency system in which pairs of propositions are related causally, logically, or conditionally.

The propositional content explicit in a discourse must be understood as a result of a series of communicative decisions made during generation of the text base. The propositional knowledge is derived from the Message Domain. Three levels of decision determine the aspects of discourse structure. The first is the Message Base, the propositional content. The second is the Text Base composed of textual organization, cohesion, and sentence structure. The final level generates sequences of sentences from the Text Base, limited by all decisions that have already been made, and produces the text. These limitations make possible the application of grammatical rules and the production of sentences that reflect the prior decisions.

If semantic memory is organized into units at varying ranks, then retrieval of semantic information should reflect this organization. Frederiksen thinks of the semantic units as a low-level frame theory since the system specifies which frames can

be built. Frames are flexible structures for representing knowledge, including semantic memory, at many levels. The model is currently programmed so that text structure can be analyzed by computer.

A further explanation of discourse inference is included in Frederiksen's (1979) theory of children's discourse comprehension. This theory is based on investigation of his six ranks of semantic units in discourse processing and recall (1977a). The purpose of the study was to show that higher order semantic processing units are formed during input or retrieval from the processes of reference or inference. At this point, Frederiksen views inference as a process integral to acquiring knowledge from text.

The text material was constructed to manipulate the propositional information and the order. Recalls were matched to the propositional data structure. Three types of measures were obtained: (a) numbers of items recalled, (b) recall probability for each item, and (c) statistics that measured pairwise dependencies among items of semantic information. The target texts were descriptive and narrative. Each was divided into three parts. The type of linking structures between the target paragraphs was varied as was the order of the linking information. The method was oral passage presentation followed by free recall.

Frederiksen contends that evidence for the ranked units--concepts, relational triple, event frame, proposition, relative system, dependency system--is found in the interitem

dependencies at recall. Dependency clustering should indicate the use of high-level inferential units. Varying the order of the targets should show interaction with link type. Three inferential processes should be evident also from the probability of recall of redundant, embedded, or subordinate target propositions: (a) selective processing, the elimination of redundancy; (b) slot-filling, placing target propositions into frames built by linking propositions; and (c) superordinate inference, using superordinate/subordinate relations to acquire new subordinate target propositions.

Results indicate primacy effects, a tendency to acquire more information from the earlier parts of a text. Causative fillers result in the acquisition of more target information. Increased levels of recall when causation is presented at the end of the passage indicates a retrieval effect. Frederiksen interprets this result as evidence for the use of high level reference and inference operations to link stored semantic information at retrieval. That the causative linking structure has greater effect when it precedes the target information is interpreted to indicate that high level inference processing units are used at acquisition, and influence subsequent text processing.

In retrieving the target information, similarity information presented last appears to be more useful than causative information. There is no difference in the effects on the number of items recalled when the semantic information order was changed.

Frederiksen interprets this finding as the effect of linking information on subsequent text processing.

Frederiksen provides evidence, derived from the non-processing of redundant information in the causative link condition, that selective inference operations affect later text processing. The evidence that embedded propositions will fill slots in frames and be recalled better was weak. However, the concept of superordinate inference was supported. A target proposition will be recalled if a superordinate proposition precedes it. Frederiksen cites this finding as evidence for the top-down control of semantic memory processing.

Lastly, there is evidence of mutual dependency of items recalled. These items form a semantic processing unit. Mean interitem correlations indicate clustering and a relation of clustering to the propositional data structure. There appears to be a close correspondence between the structure of interitem dependencies in recall and the organization of propositional structure units at the levels of ranked units previously described.

Frederiksen (1977b, 1979) addresses the inference issue directly when he discusses text comprehension as a process of relating the propositions in the text structure. For him, the question has become whether the inference essential for text comprehension is text-based or schema-based. He concludes that the situation is determined by text features, limited processing capacity, and the interaction of the component processes. For example, syntactic

complexity promotes bottom-up processing; familiar story structure promotes top-down processing. The ability to infer may be the decisive factor in efficient reading.

In his studies with young children, Frederiksen (1979) matched the propositions in children's retellings against the propositional representation of the story. The relations between the propositions are categorized according to the inferential operations that produce the propositions. Eight classes of inferential operations have been identified, 26 categories in all. Evidence from retellings of four year olds indicates that inference categories from most to least frequent are: (a) identifying operations--time shifts, (b) event generation--picture effects, (c) macrostructure operations, (d) frame operations, (e) algebraic operations--temporal ordering, (f) dependency operations, and (g) truth-value operations. The major category missing from young children's retellings was lexical operations.

Frederiksen concludes that there is a substantial amount of inference during discourse processing and that it is distributed over a wide range of inference types that can be categorized. Evidence from the analysis of the retelling protocols suggests that discourse characteristics have important effects on text-based inferences. The emphasis in this study of information processing is on operationalizing definitions of inference at the level of the proposition and interpropositional relations. For Frederiksen, inferences are text-based at the sentence level, not at the

discourse level as Reder (1976, 1979, 1980) and Crothers (1978, 1979a, 1979b) have suggested.

Hierarchical Organization of the Passage--Meyer

Content Structure Model

Meyer's (1975a, 1975b) content structure model of text explains prose analysis procedures based on a semantic grammar of propositions. Her premise is that deep structure relations are semantic, not syntactic. Her system of analysis produces a hierarchically arranged tree structure called the content structure. Nodes in the tree structure represent the concepts in the text; connecting lines indicate the spatial organization of the content. Labels in the tree structure explain and classify content relations. Text content is represented as propositions, and propositional predicates are the relations of arguments in the text structure. Frequently these are case relations (Fillmore, 1971). Propositional arguments are ideas that are related by the predicates.

Within the content structure of a passage, some ideas are subordinate to other ideas. Text propositions are located at three general levels--high, medium, and low--in the text structure. Top level ideas or superordinates have many levels of ideas beneath them and are related to the lower levels by descending lines in the tree structure. Subordinates describe superordinates. Content structure is similar to the traditional outline in that it is oriented from top to bottom and from left to right. However, unlike an outline,

all text propositions in the passage are included in the diagram, the interpropositional relations are specified, and the form of the content structure is specified by the rules of the semantic grammar of propositions.

Meyer uses two classification systems to establish hierarchical structure. The first, rhetorical predicates, are found at the top level of the structure, show how superordinate ideas are related, and give prose its overall organization. These rhetorical predicates relate large segments of the text, sometimes sentences, sometimes paragraphs or chapters. There are three kinds of explicit organizing rhetorical predicates: (a) paratactic predicates, two arguments of equal weight at the same level in the structure, that is, a problem and its solution; (b) hypotactic predicates, a superordinate argument and other arguments not at the same hierarchical level that give further information about it, that is, a problem and its details; and (c) neutral predicates in which the structural emphasis determines whether the predicate will be hypotactic or paratactic. To construct the hierarchical tree structure, it is necessary to apply rules to the content structure that specify the level at which each proposition will be placed in the structure. An additional line in the tree structure indicates special modifications that make an argument a subordinate.

The second, lexical predicates, specify role relations between content words and their arguments and use labels to classify the relations between the words. When content words describe relations

they are lexical predicates. Each node beneath a lexical predicate is related to it by a case relation which is a label. Rhetorical predicates also label content relations, but as superordinates they are not subject to subordination to a lexical predicate. Rhetorical predicates take lexical predicates as arguments.

Since all the variance in recall cannot be accounted for by content structure variation, Meyer includes a third set of relationships, the non-content aspects of the passage. This aspect of text structure is named signaling. It provides emphasis for passage organization or specific content.

Meyer's research is designed to indicate the levels of structure that are present in various forms of prose. Her early investigation of the structure of prose (Meyer and McConkie, 1973) was based on a listening task. It preceded the development of the semantic grammar of propositions and used a less formal representation of text propositions. The variables in this study were: (a) the serial position of the ideas in the passage, (b) the perceived importance of ideas in the passage, (c) the position of the ideas in the logical structure of the passage, and (d) additional repetitions of the passage.

Recalls for the two passages followed one, two, or three repetitions of the passage. Recall for the second passage was collected a second time immediately following the completion of the first recall. Idea units were the basis for scoring the number correct, the order and the frequency of recall per unit.

The findings were a negatively accelerated increase in the mean number of idea units recalled with successive presentations. Units higher in the passage hierarchy are recalled more frequently and repetition of presentation increases recall of units at all levels in approximately equal proportions. The position of idea units in the logical structure of the passage accounts for most of the variance attributable to serial position effects in the data. For all conditions, there was a .90 or greater correlation between the order of the presented idea units and the order of recall for these idea units. Units related in the hierarchical structure tended to be recalled together. If a particular unit was recalled, the unit directly above it in the logical structure was also recalled nearly 70% of the time. The overall recall was 23%. Idea units high in the logical structure are most likely to appear in both recall attempts following the second passage exposure. Meyer concludes that logical structure influences both the recall probability for any idea unit and the clustering effect. Ideas high in the structure or having more ideas descending from them are recalled more. She suggests that the logical structure of a passage is related to the cognitive structure constructed by the subject during listening.

To corroborate these findings, two series of studies (Meyer, 1975a, 1975b) examined the relationship between aspects of the content structure of 600 word passages--analyzed using the semantic grammar of propositions--and readers' recall protocols. The first

series investigated the effect of the height of information in the content structure measured by the frequency of recall for each idea unit. The second examined the degree of correspondence between content and relationship units recalled when structure was constant and passage content varied. Recall protocols were scored for both content units and relationship units. The score assigned each unit was equivalent to the number of people who recalled it.

In the first study, to look at the effect of height in the structure, the same information--the target paragraph--was placed high in the content structure of one passage version, and low in the content structure of a different passage version on the same topic. There were three topics, six passages in all. The passages were outlined according to Meyer's hierarchical model. Total length and number of words preceding and following the target passage were the same. Free recall was required immediately after reading and after one week's delay. There was also a cued recall task at the second session. Findings indicate that recall and retention over time are more likely for information high in the content structure of the passage. Cues, or lists of the content words in the target paragraphs, increase recall for information both high and low in the structure of the passage at delay.

To confirm this explanation, Meyer (1977a) obtained and analyzed immediate free recalls and immediate cued recalls. The data show that free recall indicates better memory for target paragraphs high in the structure, while cued recall assists high and low structural

positions equally. Meyer interprets these findings as support for the position that more information high in the structure is actually stored in memory and failure to recall is not an inability to retrieve the information.

Meyer collected data to confirm this position using sixth grade subjects who listened to a passage and responded in writing to 30 questions. The passage contained 17 levels in its content structure. Half the questions pertained to the top eight levels and are considered main idea questions. The second half of the questions were taken from the bottom nine levels of the structure and correspond to questions pertaining to details. For students in high, medium, and low ability groups the results indicate that more information high in the structure of the passage is remembered. The only difference is that the amount of information that is remembered decreases with the ability level of the subjects. Meyer explains her findings as subsumption. The information low in the content structure of the passage is subsumed by the more central information; it loses its identity and becomes less available for recall.

Meyer's second series of studies began with an examination of the correspondence in recall patterns for passages identical in structure, and specific role and rhetorical relations, but differing in content. Analysis by structural units revealed a .55 correlation between idea units recalled. Once again, information high in the structure is remembered better. However, the frequency of recall

for each unit is related to the pattern of specific functional relationships at the top levels. For information high in the content structure the correlation across passages is .83. For information low in the structure the correlation is .09. At a one week delay, the correlations are .67 and -.11. Content, not structure, determines recall for information low in the structure. The pattern of specific relationships in the text determines the relational pattern in the recall. Meyer's interpretation is that passages should be classified by type based on their top-level structures. Recall differences arise from role and rhetorical relations and location in the top-level configuration.

In scoring the protocols, Meyer noted that particular types of role relations and rhetorical predicates, or a combination of the two may differentially affect recall. It became evident that manner rhetorical predicates, the descriptions of how an event was performed, are not recalled regardless of the unit's position in the content structure. Therefore, a study (Meyer, 1977b; Meyer, 1979; Walker and Meyer, 1980a) was designed to see if some top-level organizational patterns facilitate memory for the entire passage more than other patterns.

Four types of top-level structures were included: (a) the response rhetorical predicate which relates a problem or question to a solution, (b) the adversative rhetorical predicate which contrasts viewpoints or relates what did happen to what did not happen, (c) the covariance rhetorical predicate which relates an antecedent to a

subsequently presented consequent, and (d) the attribution rhetorical predicate which relates a collection of attributes to an event or idea.

Four passages were used, each of 141 words. Of the total word count, 109 words were the same across the four passages and 32 were different. The same content, structure, and relationships were used for 58 of the 69 units and an additional six units were the same in structure and relationship, but not content. The remaining units were the different top-level rhetorical predicates which created the different discourse types. Passage reading was followed by free recall immediately and at a one week delay. As further measures of passage comprehension, each subject also wrote the stated message of the passage and answered questions about the passage at the second session.

The results indicate that subjects recall significantly more from passages with adversative and covariance top-level structures than from the attribution structure. Therefore, top-level structures differ in the extent to which they facilitate recall of the same information. Meyer compared the predictive power of top-level structure with other variables: sex, vocabulary ability, comprehension ability, and the amount of signaling in text. In the immediate free recall condition, top-level structure accounted for 36% of the variance and vocabulary accounted for 11%. At delay, top-level structure accounted for 56% of the variance, and there was no effect of the other variables. Meyer (1979) states that when

diagrammed, adversative and covariance structures have one more link of relationship than attribution structure.

Use of Top-Level Structure

Meyer (1979) and her students evaluated the use of top-level structure by ninth grade good, average, and poor comprehenders. They used responsive or adversative passage structures, collected free recalls immediately after reading and at a one week delay, and compared these recalls to the top-level structure of the text. They also administered a recognition test at the delayed testing session. Of the 50% of the subjects who used top-level structure, most good readers organized their recalls so that they paralleled the text structure; poor readers did not. Using the text author's top-level structure led to better recall. The use of top-level structure accounted for 44% of the variance in the immediate condition and 68% of the variance at one week's delay. The use of top-level structure also led to better discrimination of consistent information from intrusive information in the recognition test. Meyer interprets these findings as support for the position that use of top-level structures facilitates top-down retrieval. She found a strong relation between the use of text structure and retrieval in all studies with ninth graders, junior college students, graduate students and retired adults. However, when the topic is highly familiar, the effect of using top-level structure is reduced.

Reder (1980), while recognizing the efficacy of the semantic grammar of propositions for text analysis to compare the text base

to the reader protocol, criticizes Meyer's emphasis on text reproduction in the abstractive-trace theory representation (Spiro, 1975) with no cognizance of the role of inference in the comprehension process. However, this issue is addressed in the next investigation in which Walker and Meyer (1980a) tested the effect of height in the content structure on the probability of integrating two related facts. In addition to distinguishing whether integration was structural, that is, occurred at acquisition, or occurred at retrieval, two factors were manipulated: (a) Inferential premises were separated or occurred consecutively in the text, and (b) subjects were instructed either to read the passage once or to learn the information in the passage as completely as possible. Accuracy on a verification test and reaction time were recorded. The prediction was that premises integrated at acquisition would be verified faster than those retrieved separately and integrated at test.

Two stories varied three factors: (a) the height in the structure, (b) separate or consecutively presented integratable facts, and (c) the instructions, which were to read or to learn. After each story, verification of the presented sentences involved truth judgments for text statements that were either reproduced in verbatim form or implied, and justification for the decision. Following the second story, written free recalls of each story, and written tests of true and false inferences in syllogistic form were administered.

The critical item indicating retrieval and integration is true inference. Analysis of this dependent variable indicated that the subjects who learned outscored those who read, consecutive presentations were better than separate presentations, and information high in the structure was more facilitative than information low in the structure. There was an interaction between the instruction type and the presentation type. Significant reaction times were obtained for inferences based on premises that occurred together in the text.

The results, quantitatively superior integration for statements high in the content structure of the passage and qualitatively superior justification for high-level inferences, are interpreted as evidence that related facts can be integrated and that implicit text information can be acquired. In addition, inferences based on premises that occurred together in a text were verified significantly faster, that is, at almost the speed of recognition of true explicit statements, than inferences based on premises presented separately. Subjects were twice as likely to claim that these inferences had been explicitly stated in the text. These data corroborate Meyer's claim of the facilitative nature of height in text structure, and support the position that integration at acquisition facilitates decision making.

Meyer (1975a, 1980, 1981; Meyer and Rice, 1981) has used the description of hierarchical structure and rhetorical relations including signaling, to address the issue of utilization of

recognizable top-level structure. Factors that interact with signaling are the age of the subjects, reader competency, text readability, and the structural pattern of the text. Studies with university students and adults (Meyer, 1975a, 1981) indicate that good readers use top-level structure regardless of the presence of signal words.

In a study using ninth-grade students, Meyer, Brandt, and Bluth (1980), identified good and poor comprehenders and predicted that good comprehenders would use hierarchical text structure in the absence of signaling and poor comprehenders would use the default/list strategy, that is, a random, unfocused, unplanned attempt to remember something from the text. A third group, ninth-graders whose vocabulary scores exceed their comprehension scores, were expected to use top-level strategy only in the presence of signaling.

Two expository passages with problem/solution or response structures, and comparison or adversative structures, were used. One version of each passage included signal words, the other did not. The dependent measures were recalls, immediate and at one week's delay, and a recognition test for sentences from the passages at one week's delay. The passages and recalls were analyzed using Meyer's (1975a) structural analysis rules and scoring procedures. As predicted, good readers used top-level structure and recalled significantly more message units. One interesting finding that effects text structure itself is that readers were able to use the

top-level structure of the problem/solution passage more than the top-level structure of the comparison passage. The expected signaling effect for poor comprehenders with good vocabulary levels approached significance in the immediate condition, but not in the delayed condition. Among the 50% of the subjects who use top-level strategy, only 22% use it consistently. Students who use the text structure in their recall protocols recall more text-based information, especially at delay, and are more accurate in the sentence recognition task.

Meyer interprets these findings as support for her position that comprehension is a process whereby structural and schematic relationships are sought so that chunks of information can be related. The structure discovered in the text is used in a top-down manner to construct the recall protocol. Meyer (Meyer and Rice, 1983) continues to investigate the relationship of discourse types and the variables age, vocabulary, and learner strategy, as she applies her theory to learning from text.

Stage Theory and Inference--Kintsch

Theory

In Kintsch's (1974) model of semantic memory, the meaning of a text is represented by a text base constructed from propositions. Semantic memory specifies the classes of arguments each word concept can take as a predicator and the restrictions and conditions of its use. The structure of the proposition is governed by a repetition

rule that gives the text base continuity. Argument repetition determines text structure and the representation of this structure is equivalent to a connected graph. To study memory for prose, the meaning of a text must be represented through its semantic content. The representation must be capable of dealing with quantification, modality, time, tense, and the inference rules of semantic memory (Kintsch, 1976).

Each proposition contains a predicate, a verb with a designated case relation, and a set of arguments whose relation is specified by the case of the predicate. Coherence is determined by argument overlap. Order, or sequence in the text, determines the level of a proposition in the text base. Propositions appearing in the early part of the text provide cognitive access to those appearing later in the text. The discrepancy between the text base constructed by the author during writing and that constructed by the reader during comprehension results from the elaborations the reader makes from the inference capability of semantic memory. In Kintsch's system, a simple text base of four propositions may generate several surface structure representations of the same message base.

To account for text memory, the model combines data from episodic memory for list learning and a theory for the representation of meaning. Although text processing differs from list learning in the increased complexity of syntactic and semantic processing, Kintsch expected that the same cognitive processes controlled both types of learning with more elaborate processing

traces occurring during text comprehension. The theory was meant to outline organizational and retrieval phenomena in memory. Kintsch distinguishes between recognition, which is memory based or based on a simple experience, and recall, for which a more elaborate memory trace must be integrated into a network. Context connects memory traces and may affect recognition and recall. Data from sentence retrieval experiments support the two-stage model and emphasize the role of inference-making in the memory system.

Studies

Kintsch and Monk (Kintsch, 1974) provided data for the premise that text must be stored in propositional form for both comprehension and further processing. In three experiments, subjects read three types of paragraphs constructed to be syntactically simple or syntactically complex. Half the subjects read at a controlled pace and half read in a self paced manner, prior to answering inferential questions. A fourth experiment introduced irrelevant information in the paragraphs, but was the same in all other respects. Results indicate that more direct expression of the underlying propositions and lack of irrelevant information require less reading time. Memory storage appears to be independent of syntactic complexity, if reading time is not restricted, since there were no differences in the time to respond to inferences from memory. Restricted reading time decreases accuracy. Kintsch interprets these data as support for the abstract representation of meaning in memory. He assumes the occurrence of

inference at retrieval, but presents no evidence for this claim.

Additional evidence for the abstract nature of propositional representation in memory was obtained by Kintsch and Keenan (Kintsch, 1974). These experiments varied the number of propositions in a sentence while holding the number of words constant. Reading time per proposition increased as the number of propositions increased. The amount of recall was determined by the amount of reading time per proposition. In the restricted reading time condition, the percent of recall decreased. In the self paced condition, 80% of the propositions were recalled. Analysis indicates that this effect is not randomly determined. The hierarchical structure of the propositions within each sentence determined which propositions were recalled. Superordinates with the greatest number of subordinates are recalled best.

An extension of this work added the number of word concepts to the variables of the number of propositions and the length of text (Kintsch, Kozminsky, Streby, McKoon, and Keenan, 1975). Given an equal number of propositions, the number of word concepts used repeatedly as arguments may vary. Therefore, the level of redundancy varies. Two experiments controlled the number of propositions in the text base and varied the number of word concepts used as arguments for both long and short passages. Twelve history paragraphs were constructed that systematically varied the three factors. The hierarchical order of the propositions in each paragraph was specified by the rule that subordinates one

proposition to another if it contains an argument that appears in a previously listed proposition. In this context both the original set of propositions and the theme are generated intuitively, not by rule. Meyer criticizes this procedure as a shortcoming in the model (Walker and Meyer,1980b; Meyer and Rice, 1981).

Kintsch, et al. (1975) found that comparison of the few word concepts/many word concepts paragraphs in this study indicate that text bases with few arguments embed propositions as arguments of other propositions. Graphic representations of such paragraphs show a tight network structure for few-argument paragraphs with a high degree of relation. In many-argument paragraphs, relation is linear from superordinate proposition to subordinate proposition with a progression from topic to topic.

In the study, reading was followed by immediate recall scored for the presence of complete propositions only. The results indicate longer recognition time for many-argument paragraphs with greater differences for longer paragraphs. Recall was only slightly better for the few-argument paragraphs. Processing time for many-argument paragraphs was longer. The correlation between study time and the amount recalled replicates the Kintsch and Keenan (Kintsch, 1974) findings. Further replication concerns the levels effect, that is, that propositions high in the paragraph structure are recalled better, 80% for superordinate propositions to 30% for subordinate propositions. Although the primacy effect may be a confounding factor in propositional recall, these results compare

favorably to those of Meyer (1975a). Propositional recall depends on structural factors, but argument recall appears to rely on repetition both at the surface and propositional levels.

A replication using 16 harder science paragraphs yielded the same basic results for recall amounts and pattern. However, paragraph difficulty eliminated the interaction between length and number of different arguments. Replication of the first experiment as a listening task produced the same results. Replication of Experiment 1 with a 24 hour delay between the reading and the recall cued by the first superordinate proposition indicates significant effects of proposition level, delay, and interaction between levels and delay. Superordinate propositions were forgotten significantly less than subordinate propositions with delay, 55% at proposition levels 1 and 2, 73% at level 3, and 83% at level 4. Argument recall depended on the number of repetitions in both immediate and delayed conditions. Repetition nearly doubled the chances for recall. The major difference at delay was the greater number of intrusions in the recall protocols.

The study dealt only with the reproductive aspects of text recall indicated by the scoring procedure. This limitation is addressed in Kintsch's subsequent investigations. One of his basic premises is that no surface structure representation of a text is complete. The reader makes inferences to supplement sentence structure cues. Several studies (Kintsch, 1974) address this issue. In the first, propositionally identical text bases were used

to construct explicit and implicit paragraphs. The redundant propositions deleted from the implicit paragraphs were test sentences to be judged true or false. Truth judgments and response latencies were expected to indicate no differences between paragraphs. Three levels of inferences were tested: categorical, causation which was constructed from the text base, and prior knowledge. A second materials set used the deleted propositions as test sentences and added true and false text-based questions. Reading times differed for explicit and implicit paragraphs; explicit paragraphs took longer to read. There were also differences for the levels of inferences; paragraphs with level one inferences were read significantly faster than paragraphs with level two inferences and level three inferences. The error rate was greater for implicit paragraphs. Verification times were longer for long paragraphs and implicit versions of the paragraphs.

Evidence that these are valid findings comes from the lack of difference in reaction times for the text questions in explicit and implicit conditions. Since there were text version differences, the experimental predictions were not confirmed. The difference is attributed to memory for surface representation. It was hypothesized that a delay should eliminate the difference. Therefore, a partial replication of the experiment with a 20 minute delay was conducted. It confirmed the explanation for previous experimental findings.

The third experiment in the series increased the processing time

by using more complex passages. To ascertain whether the explicit/implicit difference was truly a short-term memory effect a 30 second delay condition was added to the immediate and 20 minute conditions. If the 20 minute condition is truly a long-term effect, it should replicate at a 48 hour delay. Four descriptive and four argumentative paragraphs were followed by four questions: (a) one true-explicit, (b) one true-implicit, (c) one false-explicit, and (d) one false-implicit. The explicit-implicit distinction in this study is in the question, not in the passages.

Results indicate faster reading time for descriptive paragraphs, attributed to structural complexity. More errors were made on implicit questions in all delay conditions. The reaction time differences for correct responses did not follow the prediction of no difference between 0 seconds and 30 seconds, and no difference between 20 minutes and 48 hours, although the differences did not reach statistical significance. In all conditions explicit questions were faster than implicit questions, but the difference was significant at the 0 second and 30 second delays. At 20 minutes the difference almost disappears, but it increases again at 48 hours. These findings replicate the question condition and delay effects of the first two experiments.

Kintsch (1974) interprets these data as evidence that inferences are made during reading to complete the text base in line with prior knowledge and text content. He cites Frederiksen's (1972) results as corroboration for the inference of redundant implicit

propositions during reading. Reder (1980) challenges the results in the 20 minute and 48 hour delay conditions on the basis of inadequate statistical treatment. Kintsch did not assume there would be no difference over time; an interaction between delay and explicit questions versus implicit questions would have justified the conclusion. Kintsch (1975) cautions against the validity of the conclusions in the delayed conditions in a later article, perhaps in reaction to his critics. However, he asserts that these investigations indicate that knowledge is stored as propositions whether the text representation is explicit or implicit.

McKoon (1977) provides evidence for the hierarchical nature of Kintsch's semantic memory representation. She states that propositional representation of the text base is not sequential, but is organized from the most important topic information to the least important detail information. Once the choice of the most important proposition in a text has been made, the structure is totally determined by the constraints of the repetition rule.

McKoon's study investigates the effect of the importance of a proposition in the text base structure on the speed and accuracy with which that proposition can be verified. The task was to read paragraphs and identify whether sentences from the paragraphs were true or false. Half the sentences tested superordinate propositions and half tested subordinate propositions. The hypothesis was that subordinate propositions would be verified less accurately than superordinate propositions. A 25 minute delay was introduced to

bypass the surface information effects of the immediate condition. In addition to delay of testing and propositional importance, McKoon included the variables of text length, long or short, and serial position of the propositions, first or last.

Results indicate a significant level of forgetting between the immediate and the 25 minute delay conditions. There is also an increase in the error rate. Superordinate sentences were correct significantly more of the time than subordinate sentences. The error rate was not affected by text length or serial position. Planned orthogonal comparisons showed significant effects for verification, that is, no differences between the superordinate and subordinate propositions in the immediate condition and significant difference in the delayed condition. Verification times were faster for superordinates in the immediate condition, but not at the level of significance. At delay, there was a significant effect of faster verification time for superordinate sentences. There was no effect of text length or serial position.

Since propositional importance was not significant in the error data, a replication experiment used only the short paragraphs and test sentences that were half verbatim, half paraphrase. Results show a significant error rate increase at delay, and a significantly greater error rate difference between superordinate and subordinate propositions at delay. As in the first experiment, no difference was found in mean verification time for superordinates and subordinates in the immediate condition, but a significant

difference was found in favor of faster superordinates at delay. There was no effect of serial position. There were significant differences for topic information or superordinates over time.

The lack of differences in paragraph length refute the findings of Kintsch and Monk (Kintsch, 1974), who, according to McKoon (1977), probably confounded the importance of information with text length. The memorial representation of text reflects the hierarchical position for important information in the structure of the passage. The findings support those of Kintsch and Keenan (Kintsch, 1974), Kintsch et al. (1975), and Meyer (1975a, 1975b). McKoon concludes that hierarchical text structure theories predict the finding that propositional importance affects verification time.

Process Theory--van Dijk

Transformation Through Inference

Van Dijk's (1977) process theory shows how the surface structure of discourse is transformed in cycles or stages, to a macrostructure, a superordinate representation of the text base. It explains a system of text structure which incorporates Kintsch's propositionally represented text base as the microstructure of a text which serves as the input to the macrostructure. The macrostructure is created by inference, the readers' elaborations as they comprehend the sequence of propositions that make up the text base. Reference, coherence, contiguity, and the topic of the discourse all influence the construction of the superordinate

structure that Kintsch refers to as gist memory. Van Dijk views macro-meaning as a unified representation of meaning and reference at a more global level.

In his system, the rules map macrostructure onto microstructure cyclically with increasingly stringent criteria of relevance, preserve meaning, and explain memory for text. The first rule is generalization, in which specific instances are subsumed by a superordinate constrained by the situation. The second rule, deletion, eliminates propositions that are not conditions for the interpretation of other propositions. The third rule, integration, deletes all information that has been integrated into another proposition of the discourse. The last rule is construction, a variant of integration that lacks the organizing input proposition necessary for integration. Construction combines sequences of propositions that function as one proposition at a macro-level, reduces information without deleting it, and introduces information at a macro-level that is not part of the text base, that is, the elaborations of the reader.

Van Dijk views macrostructures as analogous to topical sentences in the text because both function as superordinates. However, topic sentences are not related at the same level of description; they define possible events and actions which may follow. Macrostructures are formed during the reading process. Complexity at each level combined with human processing limitations creates further levels of macrostructure. Macrostructures organize text

memory, form the basis for recall, and constitute the basis for permanent knowledge formation.

A Processing Model—Kintsch and van Dijk

The Combined Model

Kintsch and van Dijk (1978) incorporated the components of their earlier models into a processing model that specifies three sets of operations: (a) organizing text via multiple processing into a coherent and meaningful whole, which implies differential retention; (b) condensing the meaning to gist; and (c) generating new texts from the memory traces resulting from the comprehension process. This system allows comparison of the theoretical structure of a text with that of a recall protocol. Comprehension is defined as always involving knowledge use and inference processes. The model predicts when inferences should occur to produce text coherence. During reading, relations of new text to previously read text are made in limited-capacity short-term memory. If no relation can be established, long-term memory must be searched. If a reference can be found it is reinstated in working memory, in the short-term buffer, and text coherence is maintained. When coherence is not attained, an inference must be generated or bridging must occur.

In the combined model, a hierarchy is constructed based on referential coherence, that is, the propositions most related to subsequent propositions in the discourse function as superordinates in the text base structure. Referential coherence is a result of

argument overlap between propositions. Gaps in the text base are filled by inference processes to complete passage coherence. The explicit text base is made up of propositions that cannot be assumed to be known implicitly to a reader; therefore, these explicit propositions establish the formal coherence of the discourse. In addition to the referential interrelations at the microlevel, each proposition must be related to the topic of discourse or theme at the macrolevel by the semantic mapping rules or macro-rules previously described. Implication builds macrostructure, but must preserve both the truth and the meaning of the micropropositions in the macrostructures. The entire process is controlled by a schema or frame based on world knowledge which prevents the generation of meaningless abstractions. The model also proposes to account for the organization of propositions into higher order fact units through referential coherence.

Graph structures represent the network of coherent propositions. The topmost propositions represent presuppositions as macrostructures pointing to subordinate propositions representing relevant discourse. Therefore, a coherent text base is a connected graph resulting from a cyclical process that checks argument overlap of the proposition list. It retains some propositions in the short term buffer, the point of entry for long term memory, to connect with the incoming propositions. If no connection can be established, long term memory must be searched. Inference operations are required. The nature of the text, the purpose for

which it is being read, and the reader's knowledge determine the probability of any proposition being stored in long term memory and the probability of its being recalled. The greater the number of cycles in which each proposition appears, the greater the likelihood it will be reproduced in the recall.

The components of the model are still being developed (Miller and Kintsch, 1980). The macroprocesses have been defined, not operationalized. The micropropositions are hand generated from the text using rules and procedures rather than generated by a semantic parser that would generate a conceptual text base. There is no explanation for how schema and text interact to cause inference and how these elaborations affect data. The expected shift would be from argument repetition, or formal coherence, to relations among concepts, or semantic coherence.

Empirical Support

The model was tested using graphs constructed according to the propositional sequence in the text. This procedure is a short-term memory allocation strategy called the leading edge strategy. For the investigation both text and recall protocols were graphed and compared. The dependent measure was propositional recall frequency. The parameters of the model, that is, the maximum input size per cycle, the capacity of the short-term buffer, and the reproduction probability, are manipulable and used as independent variables.

Kintsch and van Dijk have conducted several experiments using

the same text, the same procedures, and varied retention intervals—immediate, one month, and three months. After reading the passage, subjects were encouraged to reread the protocol, to add to it, and to write a 60 to 80 word summary. The recalls and summaries were typed into a computer so they could be edited continuously during the process.

Recall results show a statistically significant decline in the number of propositions by one-third to one-fourth. Kintsch and van Dijk view this decline as moderate. However, the proportion of the types of propositions recalled changed in a highly significant way over the three month interval. The number of reproductions, or direct retrieval of micropropositions and macropropositions from the text base, declined from 72% in the immediate condition to 48%. Reconstructions, or inferences that add detail, particularize, and specify, almost doubled in number. Metastatements, or comments on the structure, content, or schema of the text, quadrupled. The less text material reproduced the more the production processes added material. At immediate recall, reproductions were three times as frequent as reconstructions. At three months, their numbers were almost equal. Macropropositions were four times more frequent than micropropositions in the immediate condition. The ratio increased with delay to 12 to 1. Kintsch and van Dijk compared these recalls to a summary condition. Errors and distortions were at 1% or less at all recall intervals.

Summary results show a significant number of changes in the

three response categories, with fewer reconstructions than in the recall protocols. The summary protocols were 70% reconstructions, a few metastatements, and the remainder were reproductions.

Further analysis compares the frequency of recall predicted by the parameters of the model to the actual recall. In five of the six conditions, the prediction was accurate. In only the immediate recall was the prediction significantly different from the result. The pattern fits expectations, that is, for immediate recalls the probability of reproducing micropropositions is five times the probability at three months. Irrelevant generalizations are five times more probable at three months. Macropropositional generation changes very little over the three month period. Micropropositions are forgotten four times more than macropropositions.

Another experiment used only paragraph one of the passage and only immediate recall. Responses were 87% reproductions, 10% reconstructions, 2% metastatements, and 10% errors. The number of propositions recalled was slightly greater than the number of propositions recalled from the entire passage. Estimates of the model parameters were not differentiated here. Micropropositions and macropropositions were treated alike; there was no evidence in these data of schema controlled macro-operators.

According to Kintsch and van Dijk (1978), the limited data available at the time of publication do not provide validation for the model. One passage is not sufficient evidence. The construction of the cyclical coherence graphs followed only one

strategy, the leading edge strategy which follows propositional presentation sequence in the passage. Other arrangements are possible. The buffer capacity was arbitrarily set at four. Other capacities should be tried. Propositions were related by reference, not intrinsic meaning. Kintsch and van Dijk conclude that the model needs to be extended to show how propositional notation organizes higher-order fact units.

Supporting Studies

The process model (Kintsch and van Dijk, 1978) was applied to the problem of readability by Miller and Kintsch (1980). Their position was that comprehension difficulty should require increased processing time. In the absence of additional processes, recall should suffer. Therefore, the process model can be measured by readability assessed by measures of reading time and the number of propositions recalled. However, this study investigates only the microprocess component using short paragraphs and immediate recall.

Twenty paragraphs were analyzed into propositions chunked into coherent segments by a program that defines phrase boundaries. The structures were graphed. Each of 600 subjects read and recalled four paragraphs. The protocols were scored against the propositional microstructure of the corresponding paragraph. Most of the statements were representations of reproductive recall common to the immediate condition. The readability of each paragraph was based on paragraphs of reinstated propositions and inferences, the coherence model. It was correlated with reading time per

proposition recalled. The expected correlation was significant for 16 of the 20 paragraphs. The four non-significant paragraphs were list-like and not well structured. Recall for propositions higher in the text base was significantly better than recall for propositions lower in the text base. This implies reinstatement of micropropositions and the operation of macroprocesses.

Results indicate that the number of inferences and the number of reinstatements correlate with readability and reading time, and to a lesser extent with recall. A greater number of arguments led to longer reading time and higher readability, but had no affect on recall. Miller and Kintsch believe that these results have implications for readability levels in general and support their position that readability is an interaction between the properties of the text and the reader. The properties of the model, reinstatement and inference, do predict readability. These data are seen as support for the microprocess component of the model.

Kintsch and Yarbrough (1982) dealt with macroprocesses in an investigation of rhetorical strategies for text comprehension. Well formed structure should affect measures sensitive to macrostructure and not affect measures that rely on microstructure, for example, questions about the macrostructure versus a cloze test.

Two experiments used rhetorical structure which included signaling, and complexity. The four rhetorical forms of the first experiment were: (a) classification, (b) illustration, (c) comparison and contrast, and (d) procedural description. Definition

was added in the second experiment. Each form had a simple version and a complex version, and each version was transformed to distort the rhetorical schema while preserving the local coherence by changing signal words and reordering paragraphs. The first question asked what the essay was about; the second question was based on the main ideas in the text. The cloze test deleted every fifth word. Each subject read eight texts and answered questions or completed cloze tests. On the question dependent measure there were significant differences of good and bad rhetorical form, simple and complex versions, and text passages. In no case was the poor text better for the question measure. There were no significant differences on the cloze test. The data of the second experiment replicate these findings. The results are interpreted as support for the formation of text macrostructure, explained by the Kintsch and van Dijk (1978) model, and the presence of local microprocessing in all text structures.

The Encoding Elaboration Model--Reder and Anderson

Theory

Anderson and Reder (1979) state that comprehension of written material is dependent on the process of elaboration that takes place during reading. Elaborations establish more redundant encodings of the information. The greater the number of concepts on a given subject that are stored in memory, the more likely it is that the information can be retrieved and used. In Anderson's (1976)

explanation of memory processing, concepts are stored in a network as propositions. Each concept is linked to associated concepts, and cues serve to activate the system by initiating a search pattern that spreads through the system. The more links to other ideas a concept has, the more likely it is to be retrieved from memory. Therefore, propositions can be used in a recall or as a base on which to build additional associations.

This explanation of the network system in language processing is a component of the ACT theory (Anderson, 1976). In this theory, the surface structure representation of knowledge is arranged as abstract propositions with a noun as predicate and arguments that frequently overlap, since a predicate may also serve as an argument for another proposition. The rules by which this representation of surface structure is transformed into a network structure for memory are processors or productions which consist of a condition and an action, that is, given that the criteria of a condition are met by the propositional structure, a designated action will follow.

For purposes of illustration, the system may be represented as a linear sequence of propositions, but conceptually, and in its programmed form, it is a multilevel, interactive, network structure with nodes representing concepts and links representing relations or associations. Retrieval of information from this memory network is controlled by the set of productions that govern the activation procedures within the network. If the memory configuration specified in the condition of a production is found in the network,

either input is changed into network representation or network representation is translated into a response, depending on the conditions of the processor. This explanation of language processing serves as the basis for the encoding elaboration model.

Plausibility Studies

To support the thesis that inference is made at any stage in the comprehension process from input through recall, Reder (1976, 1979) investigated the role of elaboration in memory for prose passages. In contrast to Spiro's (1975, 1980) position of inferential reconstruction at recall, Reder demonstrated that judging the plausibility of a statement taken from the passage depends on the retrieval of the input elaboration from long term memory. Prose passages were read by the subjects; the dependent measure was a plausibililty judgment about an inference drawn from the passage. Reder intended to demonstrate that a reader computes the plausibility of the probe based on inference, not retrieval of the explicit text statement.

Ten stories were displayed sentence by sentence on a computer terminal. Reading time for each sentence was recorded. To obtain the critical sentences for evaluation, 20 subjects generated inferences at given points in the story. Another 24 subjects rated the inferences for plausibility on a seven point scale.

The three manipulated factors were inference type, treatment condition, and delay. Examples of inference type and treatment condition follow (Reder, 1979, p. 224):

1) Verb-based inferences

Text: "The heir told his father he wanted no part of his greasy food fortune."

Inference: "The heir communicated with his father."

2) High-plausible inferences

Text: "The heir decided to join Weight Watchers. Twenty-five pounds later, he realized his wife did love him after all."

Inference: "The heir had lost weight."

3) Medium-plausible inferences

Text: "Now he worried that she had been after his money all along."

Inference: "The heir had not worried about her motives before marriage."

4) PRESENTED condition

Text: "Anyway, real marital strife lay elsewhere. His wife had never revealed before marriage that she was an intellectual, that she read books. The heir did not like the fact that she read books."

Test: "The heir did not like the fact that she read books."

5) PRIMED condition

Text: "Anyway, real marital strife lay elsewhere. His wife had never revealed before marriage that she was an intellectual, that she read books."

Priming question: "The heir was delighted that she joined

the book of the month club." (false)

Test: "The heir did not like the fact that she read books."

6) NOT-PRESENTED condition

Text: same as PRIMED

Test: "The heir did not like the fact that she read books."

In the first study the probe appeared either during or immediately after the reading. In the second study the probes were repeated after a 48 hour delay. The dependent measure was correct judgment for plausibility statements. This measure is intended to represent the measurement of inference. Both reaction time and accuracy were recorded for the dependent measure. All three factors were expected to affect latency.

Results of the first study indicate that reaction time is significantly faster in the immediate condition for plausibility judgments. There was a significant main effect for high plausibility statements over both verb-based or medium plausibility statements. The presented condition was significantly faster than the not presented condition. There was a significant effect of the interaction of the treatment condition with delay. The reaction time for the presented condition slowed with delay; the difference between the primed and not presented conditions increased with delay. Inference type was not affected by treatment or delay.

Reder interpreted the lack of interaction between inference type and treatment, and the effect of inference type and treatment on reaction time, to mean that these conditions affect different stages

of processing since a treatment/delay interaction affects the same stage of processing. She concluded that readers store more than the input, that is, that readers infer during comprehension and that the content of the retrieved information enables the reader to make the plausibility judgment, not the exact statement from the text. Treatment affects retrieval by manipulating the amount of relevant information available for judgment. The inference effect in the PRESENTED condition indicates that elaborations are retrieved. The number of relevant elaborations is shown by retrieval speed. Delay leads to loss of elaboration; therefore, the greater the elaboration the greater the advantage at delay. This is indicated by the advantage of the PRIMED condition over the NOT-PRESENTED condition. In addition, the reading time for the inferences in the text is less than for other statements. According to Reder, since these statements are redundant they are processed as if they were plausibility judgments and take less time. Reder justifies these findings by applying her model of the elaboration hypothesis.

Experiment II is designed to test the prediction of the model, relative to the retrieval stage, that the advantage of priming would continue with longer delays. The major difference in the two studies is the addition of the 48 hour delay.

Results indicate significance for all the main effects, and for the interaction between treatment and delay, but no significant interaction between treatment and inference type. The major difference between Experiments I and II was that delay increased the

difference between the PRIMED and NOT-PRESENTED conditions. Significant differences were found in the reaction times between inference types. There was a significant difference in the latencies between the PRIMED and NOT-PRESENTED conditions immediately after reading. This difference is attributed to the tendency to elaborate more in the PRIMED condition than in the NOT-PRESENTED condition. Split half analysis indicated that subjects in Experiment I had more exposure to the priming questions and learned to attend to that information more quickly. The difference in results was in the second half of the data.

Post hoc procedures confirmed that extraneous variables were not responsible for the faster reading times for the high plausible inference statements. Based on the effect of inference type, Reder concluded that probe plausibility is computed by retrieving the elaboration made at input from long term memory. The explicit text statement is not retrieved. The evidence cited is the effect of inference type.

Further investigation (Reder, 1982) of plausibility judgments in contrast to fact retrieval as measures of comprehension provide data for Reder's position that both strategies are employed despite the task requirements, but that plausibility is faster after delay. It is more efficient to select a few relevant facts and compute the answer than to complete a search for an exact match. The dependent measure in these later investigations added recognition of a test probe to plausibility judgments. Testing was conducted immediately

after reading, after a twenty minute delay, and two days later. The stories used were those from earlier studies. Results show that reaction times for recognition of a test probe increase with delay while reaction times for plausibility judgments decrease with delay. The slight accuracy advantage for plausibility increases by 16% over two days. Reder's data confirm the prediction that subjects should be faster to judge a statement as plausible when it was not presented than to recognize it when it was presented.

Reder compares her findings to the text processing position that information represented higher in the tree structure of the passage is recalled better. She contends that these findings can be explained by the greater plausibility of the central propositions, not their position. Higher level ideas are implied by the lower level ideas and are embellished more. These differences make central ideas easier to reconstruct and to verify.

Memory Studies

In a series of investigations on learning information from text, Reder and Anderson (1980, 1982) found that the theoretical predictions of the elaboration hypothesis (Reder, 1976, 1979) and the ACT model (Anderson, 1976) were not supported by the data. The hypotheses for these studies were that details embellish main points, and facilitate their reconstruction, especially at delayed testing.

Reder and Anderson (1980) conducted seven experiments in which the allowed reading time and delay intervals were manipulated. The

materials were two first chapters from college level texts and summaries approximately one-fifth the length, containing only main points. The dependent measure was accuracy on a series of 32 questions on each topic, half interrogating specific assertions, the other half requiring integration of several points.

The first two studies found a significant advantage for the summary form at immediate and at one week testing, 75.2% accuracy to 65.3%. In the third experiment study time for the chapter was three times as long as that allowed for the summary. This procedural change confirmed the findings, though it reduced the difference interval.

Student subjects were asked to return six to twelve months later--experiment 7. New questions were asked. A slight advantage for the summary form was retained. However, there was an interaction between the text type and the delay, and possible floor effects since the accuracy performance on the questions approached the chance level.

The fourth study tried to control for the effects of memory failure by having the text available during the question answering. Although effects of memory cannot be completely removed, the results of question accuracy are clearly in favor of the summary form. Experiment five used split halves of chapters to see if second half learning was facilitated by first half chapter form or summary form. The study time allowed for each half was the same. The findings, marginally significant, indicate a slight advantage for

studying each half in the same form. A more important finding is that there is a slight advantage for studying the first half in summary form for both text and summary second halves. The results are the same for experiment six, a replication of experiment five, in which the main points were underlined in the text form.

The next series of investigations (Reder and Anderson, 1982) were intended to establish causation for the summary advantage. The authors claim that the factors influencing this advantage, reading main points at spaced intervals and the presence of details that draw attention away from the main points, cannot be separated in the previous series (Reder and Anderson, 1980). They hypothesized an advantage for spaced study for the main points and an advantage for focused attention on the main points in the summary condition.

Two conditions were established that controlled reading time. The embellished-massed condition approximates the typical prose condition; the unembellished-spaced condition approximates the summary condition. The two factors of each condition were interchanged creating four conditions: (a) embellished-massed, (b) embellished-spaced, (c) unembellished-massed, and (d) unembellished-spaced. Presentation conditions for the four topics were computer controlled and reflected the descriptions of the study conditions. The primary dependent measure was question-response accuracy on 32 questions per topic. The second dependent measure was response latency.

The results indicate that there was an advantage for spaced

practice and the unembellished condition when the questions immediately followed the reading. The questions were asked after all four topics had been completed separately. The embellished-spaced condition led to more accuracy than the embellished-massed condition, and the unembellished-massed condition led to more accuracy than the embellished-massed condition. In any condition, significance was found for unembellished text. The spaced study effect was not significant.

A replication used a more sensitive dependent measure to establish the effects of spacing, that is, the accuracy of answers to probed recall questions, primarily wh questions. Significant main effects were found for unembellished text, spaced study, and the immediate text condition. Significant interaction for spacing and delay, that is, the benefit of spacing, decreased with delay. A clear advantage for the unembellished form, independent of spaced study, was established.

A third study to establish the effect of study time on the results of experiment two used only spaced practice. The main points were exposed for an equal amount of time and the details were exposed in a separate presentation following each main point. Again, the unembellished condition led to superior question accuracy when compared to the question accuracy following the embellished condition. There was no significant effect of delay or interaction of delay with the manipulation of embellishment. Details appear to limit the retention of main points even when they are not competing

for study time. Reder and Anderson reluctantly conclude that detail, though it may add interest and credibility, interferes with memory for central ideas.

In a more recent study, Phifer, McNickle, Ronning, and Glover (1983) challenge the Reder and Anderson (1980, 1982) findings. They found that memory for central facts was significantly greater when the central facts were supported by two or three supporting details than when the central facts were supported by one supporting detail or no supporting details. In a repetition of the Reder and Anderson (1980) study, Phifer et al. found results that refuted the finding of summary condition superiority. In the replication study, the allotted reading time for summary or text passages was adjusted to each subject's reading speed, equating the processing limitation imposed by time constraints. Given this personalization of reading time, the related condition yielded higher percentages of central facts recalled.

Elaboration and Depth of Processing

Support for the encoding elaboration model can be derived from Bradshaw and Anderson (1982). Their study investigated the relation between elaboration and depth of processing as evidenced by better recall from elaborated text conditions. They conducted three experiments which manipulated the amount and type of elaboration in the text. Recall accuracy and response latency were the dependent measures. The hypothesis under investigation was that redundancy, that is, the interconnectedness of propositions, is the important

factor in improving text recall.

Four conditions for fact presentation were established: (a) Central facts were presented alone, (b) central facts were accompanied by two highly related causative supporting facts, (c) central facts were accompanied by two highly related facts that resulted from the central fact, and (d) central facts were accompanied by two unrelated supporting details. Best recall was predicted for the two related conditions and poorest recall was predicted for the unrelated condition.

The materials, displayed on the screen of a computer terminal, were seven biographical facts about each of 28 famous historical figures. Each subject saw a subset of the facts about each figure in one of the four conditions. The relationship of the supporting details to the central fact was stated explicitly. The facts were displayed on the screen for a given number of seconds. Memorization of each set of facts was required. Memory for each set was tested by requiring the subject to supply the name of the figure and the specific relation of the facts in the set. Correct identification of each fact set continued until it was remembered, then it was dropped from the set. This process continued until all items were known by each subject. Recall was cued by the name of each historical figure, and the task was to write down each remembered fact and the relation of the set of facts. A reaction time task requiring identification of test facts versus foils, which mis-paired the name of one historical figure with a fact about

another, completed the first session. One week later both dependent measures were repeated.

Results indicate that it takes fewer trials to learn the facts in the related conditions and most trials to learn the facts in the single condition. These results hold true whether the means for each condition are determined from the dropout rate for a set of facts or from the dropout rate for the central fact in each set. Therefore, there were significant main effects of item condition. The recalls, scored for gist, indicated significant condition effects. Unrelated facts were not recalled as well as related facts and single facts. There was no clear advantage for related facts over single facts in the percentage of recall which was high.

A replication experiment attempted to reduce the initial learning of the facts to see if an advantage for the related condition could be established by eliminating the cued recall task in the immediate condition. The results of the dropout phase confirmed those of the first experiment. The cued recall in the delayed condition showed a significant difference for the unrelated condition, and a non-significant pattern of higher recall for the related conditions in favor of the resulted-in condition, compared to the single condition. These results are closer to expectations of the elaboration model.

Initial learning was reduced further in the third experiment. Both dependent measures were eliminated from the first session. At the second session, the reaction time task used thematically related

foils to force more careful decisions. Results show that the means from the dropout phase maintain the same pattern, but the main effect of item condition is not significant. The delayed recall showed a significant difference between the related and single conditions. This finding is in line with the pattern seen in the first two experiments. In all three experiments, the resulted-in condition provided the highest levels of means in the recalls. The authors claim support for the elaboration hypothesis as an explantion for depth of processing effects predicted by the ACT model (Anderson, 1976).

Text Structure Models and Issues in Comprehension

The five reviewed models have common features, distinctively defined. Each model represents the surface structure of the text in rule-governed propositional form, arranges the propositions schematically to represent semantic memory, and compares text based analysis to the reader's recall protocol. Each model identifies relations in text structure, deals with redundancy in the text-base, and with implications for the retention of information. In contrast, each model deals differently with the critical issues of reader structure, learning and retention, and information retrieval.

Reader Structure

Although each model explains the relation of the propositional text base to the structure created by the reader in the process of passage comprehension, issues that affect the

process--hierarchicality, redundancy, inference--are viewed differently. Crothers (1972a, 1972b, 1979b) finds that frequency of concept occurrence in the paragraph and the reader's selective emphasis creates a foregrounded structure that mediates between the hierarchical and underlying structures of the text. In Crothers's theory, this macrostructure reflects inference and interconnectedness and appears to describe the structure developed by the reader.

Frederiksen (1975c, 1979) assesses semantic knowledge in discourse in reference to relations in text structure. Referential coherence is represented by a logical structure graph; propositional concepts are placed in networks according to their semantic relations. Conditions established at acquisition and discourse characteristics effect memory structure. High level inference processing units are used at acquisition and influence subsequent processing.

Meyer's (1975a, 1975b) structures detail the author's knowledge base represented in the surface structure of the text, but do not deal with the generation of a text base by the reader. She emphasizes the hierarchical arrangement of text structures and the superordinate/subordinate arrangement of ideas. Subordinates describe superordinates; superordinates subsume subordinates. Reader structure is dealt with as a reflection of author structure, not a constructive process of integration.

For Kintsch (1974) the reader's text base is constructed from

propositions governed by argument repetition and the sequence of text presentation. Coherence is derived from argument overlap. The discrepancy between author and reader structure results from the elaborations made by the reader from the inference capability of semantic memory. Van Dijk's (1977) process theory incorporates Kintsch's propositional representation of text as the microstructure that is transformed by inference processes to the macrostructure, the gist of the text retained in long-term-memory.

Reder and Anderson (1979) describe the structure created by the reader from text propositions as a process of elaboration at input as new concepts are associated with existing nodes in the network of long-term-memory. Although nodes may have subnodes, this system is not predominantly hierarchical; it is multilevel and interactive.

All the models deal with text proposition relatedness: Crothers explains relatedness at the passage level through his foregrounded structure, Frederiksen at the semantic level, Meyer at the level of rhetorical relations, Kintsch and van Dijk through the cyclical construction of the macrostructure, and Reder through the plausibility of text-based inference.

Learning and Retention

An important issue underlying every model of text structure is how the comparison of the structure of the text base and the structure created by the reader reflect what is learned and retained. Crothers's (1972a, 1972b) theory, that the theme of the text controls the recall through the logical relations in the text,

made no allowance for surface structure, concept redundancy or the reader's elaborations. His process approach to inferences made during reading (Crothers, 1979b) and text cohesion (Crothers, 1979a) replaced the emphasis on connectives and set relations. His data do not support hierarchically based learning and retention.

Frederiksen's (1975c, 1977a, 1979) structures reflect cross propositional inferences that create cohesion in text. The multilevel structure created from the text analysis of surface structure duplicates semantic knowledge. Analysis of the structure of recall indicates that cross propositional inferences are made by the reader since the text is recalled in related chunks of information. Frederiksen states that propositional content is understood in relation to decisions made during interaction with text propositions, organization, and processing decisions. Higher order semantic processing units are formed from inference and reference. Hierarchical organization for learning and retention is seen in recall of mutually dependent items.

Meyer's (1975a) structures detail the author's knowledge base, represented in the surface structure of the text, but do not deal with the generation of a text base by the reader. However, she presents evidence for the retention of concepts higher in the hierarchical representation of the text; superordinates subsume subordinates. She also presents evidence for the position that certain rhetorical relations are recalled better than others, that top-level structures differ in the facilitation of recall. For

Meyer (Meyer, Brandt, and Bluth, 1980), comprehension is a process whereby structural and schematic relationships are sought by the reader to relate passage information.

In the Kintsch and van Dijk (1978) process model of text structure and comprehension, abstract propositional representation of surface structure, rules to generate a gist representation of text meaning, and the representation or referential coherence in a structural hierarchy, reflect both the text base and the recall protocol. This model accounts for the processing limitations of human memory that lead to the formation of the macrostructure through differential retention.

The Reder and Anderson (1979) encoding elaboration model represents verbatim text propositions and inferential elaborations in the multilevel network representation of human memory. Referential coherence is represented in the links that connect concept nodes. Redundancy strengthens nodes and associations. Reder (1982) asserts that concepts are stored as elaborations on the text, or inferences. Therefore, recall of inferences is seen to result from a more efficient way to search memory than recall of verbatim propositions.

Information Retrieval

Another important issue in text structure theory is how information is retrieved by a reader from the semantic knowledge structure to human memory. The premise is that the text based analysis reflects the author's semantic memory structure and the

recall protocol reflects the reader's semantic memory structure. When the two are compared, the findings should indicate inconsistencies between the structures.

In the several theories of text structure that represent knowledge as abstract semantic propositions (Kintsch, 1974; Meyer, 1975a, 1975b; Kintsch and van Dijk, 1978) the hierarchical arrangement of propositions, or the centrality of the concepts within the hierarchy (Meyer and McConkie, 1973; Meyer, 1975a, 1975b, 1977a) constrain access to the details, or embellishments, by indicating that propositions higher in the hierarchical arrangement serve as presuppositions to those lower in the arrangement. In other words, access to detail is dependent on having retrieved the superordinate. Meyer (1979; Meyer, Brandt, and Bluth, 1980) contends that the use of top-level structure facilitates retrieval from semantic memory; her studies present evidence for top-down processing.

For Frederiksen (1977a, 1979), semantic memory is organized into units at varying ranks; retrieval of semantic information reflects this organization. High level reference and inference operations link stored semantic information at retrieval. Superordinate propositional recall is evidence for top-down control of semantic memory processing. Frederiksen (1975c, 1979) found that information is recalled in related chunks of propositions. He considers this mutual dependency of items recalled as evidence for a semantic processing unit. In Frederiksen's theory, retrieval depends on text

features, limited processing capacity, and the interaction of component processing.

Crothers's (1972a) model attempted to graph recalls based on the premise that subordinates imply superordinates. Crothers (1979b) found information retrieval to be dependent on the integration of text based inferences with information in semantic memory. Kintsch and van Dijk (1978) claim that recall for superordinates reflect human processing and that only through a superordinate can a detail be accessed; once readers construct their gist representations based on referential coherence, only memory for the gist is retained.

According to the Redundancy Hypothesis (Reder and Anderson, 1980), embellishments allow reconstruction of the main ideas; the details imply the main points. The arrangement of concepts is viewed as a network at all levels (Anderson, 1976), not a hierarchy with a relational structure. Given a central fact and two supporting details, the central fact can be inferred from the details. In addition, the details or supporting arguments can be reconstructed from the central fact. In the Reder and Anderson (1979) model, based on inference and redundancy, the network can be entered at any cued or recalled node. With unrestricted access, memory search is multilevel and associative. In this sense, it represents the diversity of human memory processing. The superordinate, or central fact, can be accessed if a subordinate concept is accessed first just as access to a detail can follow from association with a superordinate.

Summary

The immediate purpose of text structure models is to compare the schematic representation of text with the recall protocol which represents reader comprehension and memory. As Kintsch (1982) observes, theories of text representation provide the means to investigate the structure/comprehension relation. Each model provides rules and procedures for representing a text base. Each theory has been modified in response to empirical findings. No researcher claims to have addressed all the factors involved in text comprehension. However, as each model developed, it became a multilevel structure directed toward explaining inferential processing. The ultimate objective must be to indicate text structures that facilitate comprehension in specific contexts.

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